FISHERY DATA SERIES NO. 90-5

STOCK ORIGINS OF COHO SALMON IN UPPER COOK INLET, ALASKA, DURING 1989[1]

By

Douglas Vincent-Lang

Alaska Department of Fish and Game
Division of Sport Fish
Anchorage, Alaska

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ABSTRACT

Differences in growth patterns on scales from four stocks of coho salmon *Oncorhynchus kisutch* were investigated for use in allocating harvests in the mixed-stock, commercial fisheries of upper Cook Inlet, Alaska. Stocks in the investigation came from the Susitna, Little Susitna, Swanson, and Kenai Rivers. Scales were collected from escapements and inriver sport fisheries. Because coho salmon age 2.1 (4 years old) dominated both the sampled catches and escapements, linear discriminant functions were built only for this age group. Overall accuracy of the best four-stock classification model was 56 percent; that is, the best linear discriminant function correctly classified scales to their known river of origin only 56 percent of the time. The poor performance of the model suggests little utility for accurately estimating stock-specific contributions to the mixed-stock, commercial fisheries. Differences in mean length-at-age among escapements and harvests were also discarded as a means of estimating contributions during a year when these differences almost disappeared because of the season closure of the largest commercial fishery in the Inlet. Given currently available technologies, stock allocations of coho salmon harvested in the mixed-stock, marine fisheries of upper Cook Inlet could most likely be achieved through a coded-wire tag study.

KEY WORDS: coho salmon, *Oncorhynchus kisutch*, upper Cook Inlet, stock separation, commercial fishery, age, sex, length, scale patterns analyses, length-at-age, Kenai River, Susitna River, Swanson River, Little Susitna River, linear discriminant functions, classification accuracy.

INTRODUCTION

Tributaries to upper Cook Inlet (UCI) (Figure 1) support the largest sport fisheries for sea-run coho salmon *Oncorhynchus kisutch* in Alaska (Mills 1989). During the years 1977 through 1988, about 55% of the sea-run coho salmon harvested by sport anglers statewide were from UCI tributaries (Table 1). The largest fisheries occur in tributaries on the Kenai Peninsula, notably the Kenai, Swanson, Ninilchik, and Anchor Rivers and Deep Creek. An estimated 87,238 coho salmon were harvested by sport anglers fishing Kenai Peninsula waters during 1988 (Table 2). Extensive fisheries also occur on various tributaries throughout the Susitna River Valley, chiefly on the Deshka River and Lake and Alexander Creeks. Notable fisheries also occur in western UCI, notably on the Kustatan, Chuit, and Theodore Rivers. Anglers fishing Susitna River and western tributaries of UCI during 1988 harvested an estimated 43,258 coho salmon. Extensive fisheries also occur on the Little Susitna River and other waters flowing into northern UCI. Anglers fishing these waters harvested an estimated 46,676 coho salmon during 1988.

The stocks of coho salmon in UCI are also extensively exploited in the commercial fisheries in UCI (Figure 2). During the years 1977 through 1988, an average of just over 460,000 coho salmon were harvested in the drift and set net fisheries of UCI (Table 3). The drift net fishery in the Central District is typically the largest of the commercial fisheries accounting for about 50% of the harvest[1]. The set net fisheries in the Central and Northern Districts of UCI harvested just over 280,000 coho salmon during 1988 with the fisheries on the eastside of the Central District and the westside of the Northern District being the largest (Table 4).

Currently, the stock-specific origins of coho salmon harvested in the mixed-stock, marine fisheries of UCI can not be determined. Inriver production and optimum harvest can not be defined because of the unknown quantity of each stock which is removed by marine fisheries. Limited analysis of tagging/ recovery of migrating adult coho salmon in UCI (Tarbox 1988) and differences in length-at-age (Wadman 1971) and scale patterns (Bethe 1977, Robertson 1979) suggests that the stock-specific origins of the mixed-stock harvests may be determined by comparing these statistics for known stocks.

A study began in 1987 to evaluate the feasibility of determining the stock-specific origins of coho salmon harvested in the mixed-stock, commercial fisheries of UCI. Effort during the first year of the program focused on standardizing the collection and reading of scales collected from coho salmon throughout UCI and coalescing and evaluating historical data to gain a better understanding of how the commercial fishery exploits different stocks of coho salmon. Analyses conducted during the second year of the program focused on evaluating the feasibility of using migratory timing and length-at-age statistics to determine the stock compositions of the mixed-stock harvests of

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[1] The drift net fishery of the Central District was closed during 1989 due to the spill of oil from the tanker EXXON Valdez.

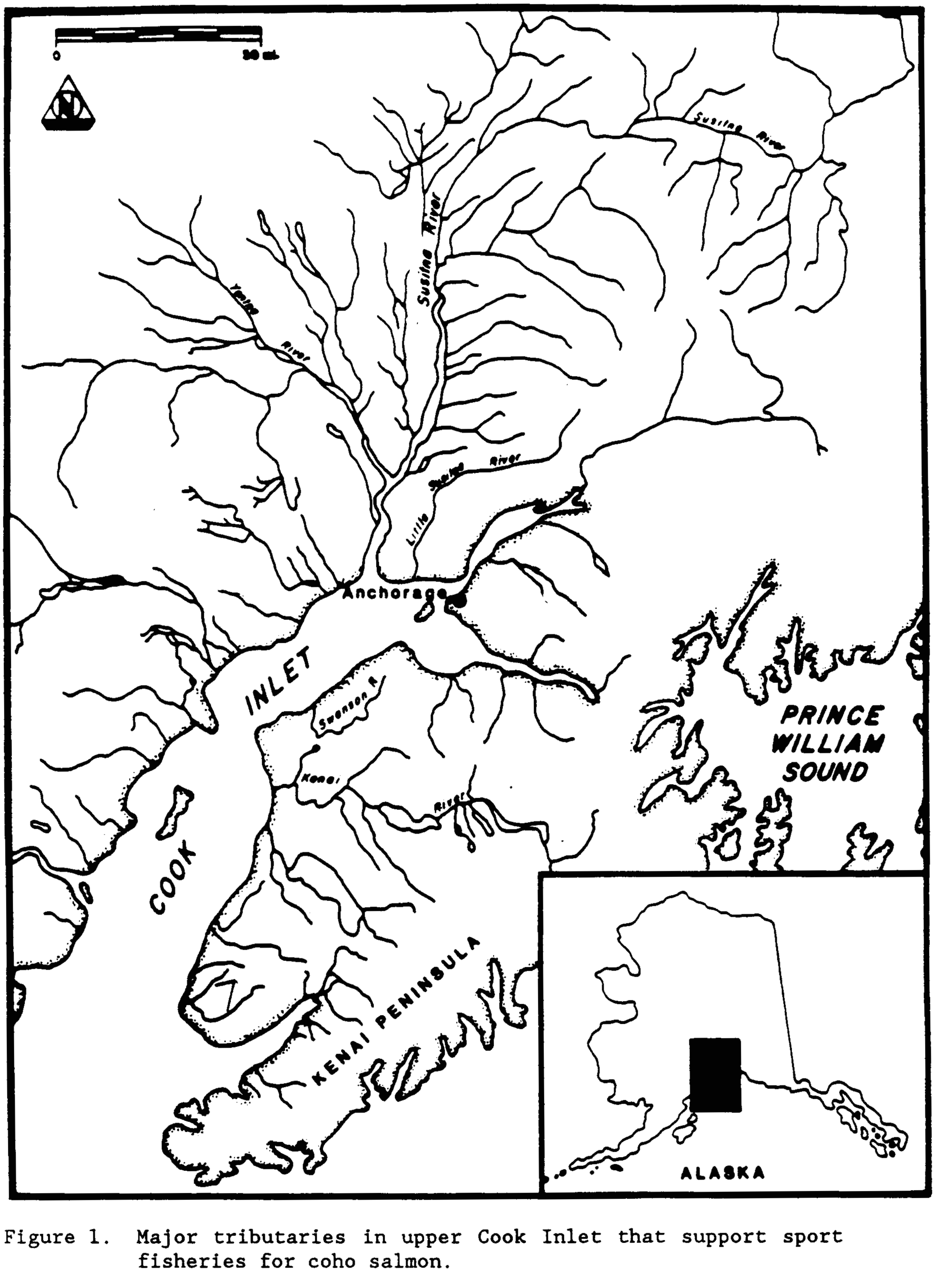

Figure 1. Major tributaries in upper Cook Inlet that support sport fisheries for coho salmon.

Table 1. Sport harvests of sea-run coho salmon in upper Cook Inlet as a comparison of the statewide sport harvest for the years 1977 through 1988 (Mills 1989).

Year	Statewide Harvest	Upper Cook Inlet Harvest	Percent of Statewide Harvest
1977	104,991	51,907	49.4
1978	131,945	65,230	49.5
1979	119,329	65,175	54.6
1980	164,302	96,032	58.4
1981	125,666	72,835	58.0
1982	195,550	106,581	54.5
1983	149,270	63,994	42.9
1984	238,536	134,008	56.2
1985	200,773	107,008	53.6
1986	255,887	136,231	53.2
1987	235,435	133,818	56.8
1988	281,450	177,172	62.9
Mean	183,595	100,881	54.9

Table 2. Harvests of sea-run coho salmon in selected sport fisheries of upper Cook Inlet during 1988 (Mills 1989).

Area	Harvest	Percent of UCI Harvest	Percent of Statewide Harvest
Kenai Peninsula	87,238	49.2	31.0
Susitna River/ Western Cook Inlet	43,258	24.4	15.4
Little Susitna River/ Northern Cook Inlet	46,676	26.4	16.5
Total: Upper Cook Inlet	177,172	100.0	62.9
Statewide	281,450		

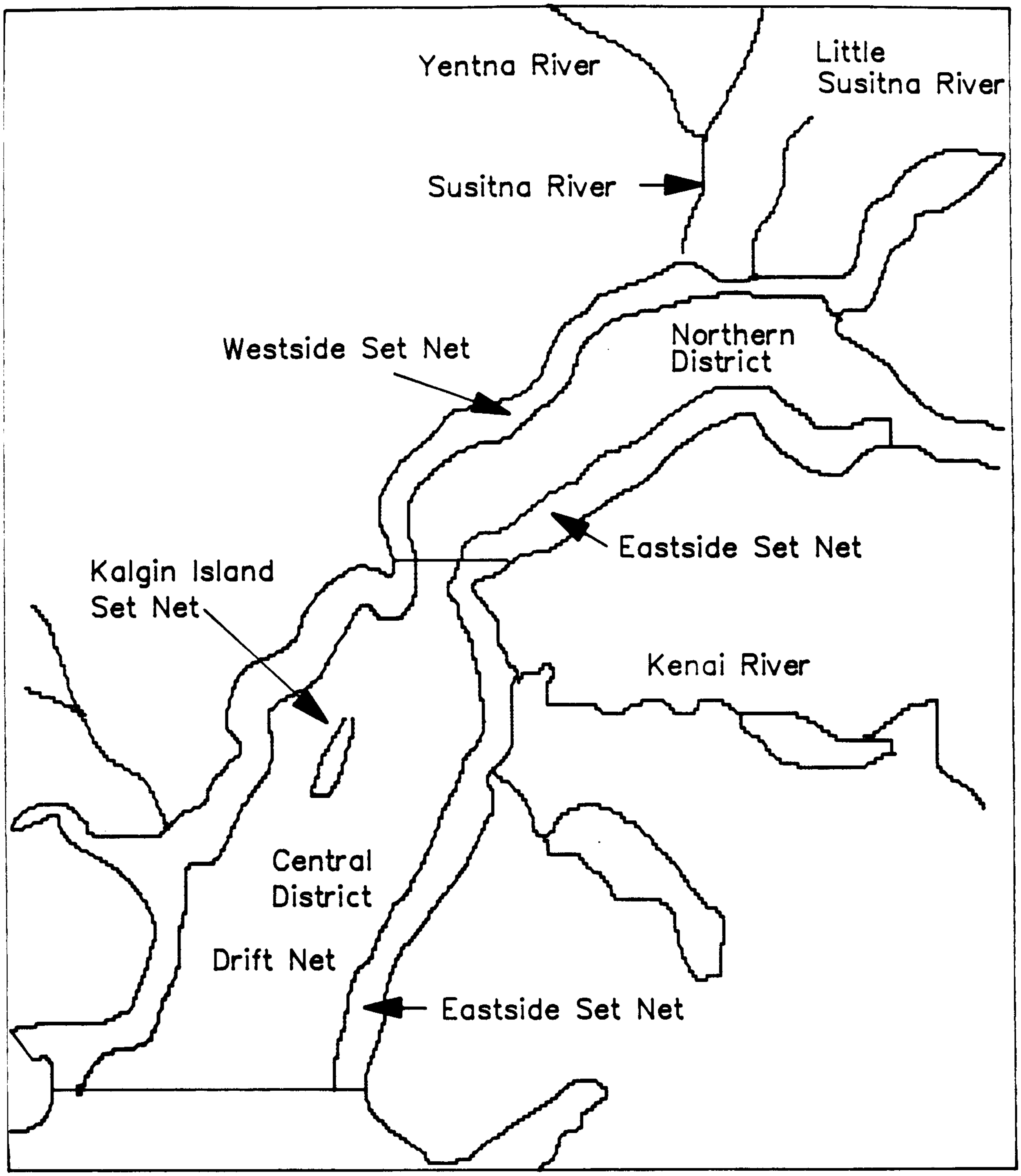

Figure 2. Major commercial fisheries in upper Cook Inlet, Alaska.

Table 3. Harvests of coho salmon in the commercial fisheries of upper Cook Inlet for the years 1977 through 1988.

Year	Harvest
1977	192,599
1978	219,360
1979	265,166
1980	261,600
1981	485,148
1982	793,937
1983	516,322
1984	442,619
1985	619,924
1986	739,292
1987	451,404
1988	560,022
Mean	462,283

Table 4. Harvests of coho salmon in the commercial fisheries of upper Cook Inlet, by fishery, during 1988.

District	Fishery	Harvest	Percent of Total
Central	Drift Net	277,803	49.8
	Westside Set Net	49,531	8.9
	Eastside Set Net	55,419	10.0
	Kalgin Set Net	27,527	5.0
	Sub Total	410,280	73.7
Northern	Eastside Set Net	26,386	4.7
	Westside Set Net	123,356	22.0
	Sub Total	149,742	26.7
TOTAL		560,022	100.0

coho salmon. Differences in migratory timing, length-at-age, and marine scale pattern statistics were found among the different stocks of coho salmon in UCI (Vincent-Lang and McBride 1989). However, none of these could be used to accurately discriminate among stocks. Therefore, the feasibility of using scale patterns analyses (Worlund and Fredin 1962, Cook and Lord 1978, Pella and Robertson 1979) to estimate stock compositions in the mixed-stock, commercial fisheries was evaluated during 1989.

The objectives of the 1989-1990 study were to:

1. Estimate the age and sex compositions and mean length-at-age (by sex) of coho salmon returning to the Susitna, Little Susitna, Kenai, and Swanson Rivers.

2. Estimate entry timing of coho salmon into the Susitna, Little Susitna, Kenai, and Swanson Rivers.

3. Estimate the age and sex compositions and mean length-at-age (by sex) of coho salmon harvested in the commercial drift net and set net fisheries on the eastside and westside of the Central District and in the set net fisheries on the westside of the Northern District.

4. Estimate the migratory timing of coho salmon harvested in the commercial drift net and set net fisheries on the eastside and westside of the Central District and in the set net fishery on the westside of the Northern District.

5. Evaluate the classification accuracy of a linear discriminant function (LDF) based on measurements and counts of circuli from freshwater and first-year-marine zones on scales from coho salmon from the Susitna, Little Susitna, Kenai, and Swanson Rivers.

METHODS

Age, Sex, and Length Data

Coho salmon were sampled from the Susitna, Little Susitna, Kenai, and Swanson Rivers using creel surveys and weirs; from fishwheels and the drift net and set net fisheries on the eastside and westside of the Central District; and from the set net fishery on the westside of the Northern District (Table 5). Fish were measured from mid-eye to fork-of-tail to the nearest one-half centimeter, and sex was determined from inspection of external characteristics. Three scales were also removed from the preferred area (Clutter and Whitesel 1956) and mounted on adhesive coated cards. Cards were

Table 5. Commercial fisheries and tributaries of upper Cook Inlet sampled for timing and biological data during 1989.

District	Fishery	Number of Fish
Central	Eastside Set Net	1,423
	Westside Set Net	440
Northern	Westside Set Net	1,040
	Total	2,903

Tributary	Method of Collection	Number of Fish
Susitna River Drainage	Weir	1,568
Little Susitna River	Creel/Weir	1,186
Kenai River	Creel	277
Swanson River	Weir	203
	Total	3,234

later thermohydraulically pressed against plastic cards. Scale impressions were displayed on a microfiche reader to determine age[2]. One person determined the ages of all samples.

Proportions in age compositions were estimated for each sampling location. Letting p_i be the estimated proportion of age group *i*, the variance of p_i was estimated as (Scheaffer et al. 1979):

$$V(p_i) = p_i(1-p_i)/(n-1) \qquad (1)$$

where n is the number of coho salmon sampled. Chi square tests were used to test for significant differences ($\alpha = 0.05$) in age compositions between individual freshwater escapements and commercial fisheries.

Mean length-at-age by sex and its variance were estimated for each sample using standard normal procedures.

Timing Data

Timing was estimated by plotting weekly statistics from fisheries, weirs, and fishwheels. The entry timing of coho salmon into the Susitna River was estimated from counts through fishwheels at the Yentna River (approximately 51 km from salt water), a major tributary to the Susitna River. The entry timing of coho salmon stocks into the Little Susitna River was estimated based on counts through a weir approximately 55 km from salt water. The entry timing of coho salmon stocks into the Kenai River was estimated from catch-per-unit-effort (CPUE) from the sport fishery on the lower Kenai River (ranging from 5 km to 50 km from salt water). Entry timing of coho salmon stocks into the Swanson River was estimated from daily escapements through a weir approximately 1 km upstream of salt water. Timing of coho salmon harvests in the commercial fisheries was estimated from daily harvests as reported on fish tickets compiled by the ADF&G Division of Commercial Fisheries from sales receipts.

Timing was used to determine stocks of known origin that could be available in the mixed-stock, commercial fisheries. Availability was determined from migratory rates for tagged coho salmon in UCI (Tarbox 1988). These data indicate that coho salmon could be available to a commercial fishery for a period up to 25 days.

Scale Pattern Analyses

Aspects of freshwater and first-marine zones of scales were measured from a randomly drawn sub-sample of age 2.1 coho salmon collected from the four freshwater escapements (Table 6). Scale impressions were projected at 100X magnification using equipment similar to that described by Ryan and Christie

[2] Expression of age of coho salmon follows the European method. The numeral preceding the decimal represents the number of freshwater annuli, whereas the numeral following the decimal represents the number of marine annuli. Total age is the sum of these two numerals plus one.

Table 6. Number of scales of age 2.1 coho salmon of known origin measured for scale pattern analyses.

Drainage		Number of Fish
Susitna River		72
Little Susitna River		45
Kenai River		116
Swanson River		60
	Total	293

(1976). Scale impressions were measured on a Talos digitizing tablet and the measurements recorded on a COMPAQ microcomputer. Distances between circuli (growth rings) were measured as well as the number of circuli for each of the following growth zones (Figure 3): (1) first-freshwater, (2) second-freshwater, (2) the plus-growth (end of last freshwater annulus to end of freshwater growth), and (4) first-marine. All measurements were made along an axes 17-1/2° dorsal from the anterior-posterior axis of the scales. In total, 109 measurements were made on each scale.

For each of the four escapements (Susitna, Little Susitna, Kenai, and Swanson Rivers), five descriptive statistics were calculated for each of the 109 scale variables: the mean, the standard error, the sample size, and the minimum and maximum values observed. F-statistics with which to test the equality of group means for each of the four stocks were also calculated. In addition, a correlation matrix and negative correlation summary were calculated between each of the 109 variables to describe possible relationships between variables. The scale variable with the highest F-statistic was selected as the primary input variable for the discriminant analyses. Secondary variables for input into the discriminant analyses were selected based on their correlation to the primary variable and their F-statistic. Variables with both a high negative correlation to the primary variable and high F-statistics were chosen as secondary input variables (Cochran 1964).

A discriminant analyses was performed using the correlated set of primary and secondary variables using linear discriminant functions (LDF) based on differences in scale growth for the four stocks of known origin (Fisher 1936). A leaving-one-out procedure (Lachenbruch 1967) was used to estimate the accuracy of the classification models. Variables were added to model until classification accuracy did not change significantly.

RESULTS

1989 Commercial Fisheries

Just over 5.5 million salmon were harvested by commercial fisheries in UCI during 1989. The composition of the harvest during 1989 was 90.0% sockeye salmon, 2.2% chum salmon, 6.1% coho salmon, 1.2% pink salmon, and 0.5% chinook salmon (Figure 4). This compares with a historical harvest composition of 59.4% sockeye salmon, 15.9% pink salmon, 16.3% chum salmon, 8.1% coho salmon, and 0.3% chinook salmon. The historical mean harvest of the commercial fishery in UCI is 4.2 million salmon.

The harvest of coho salmon in UCI during 1989 was 339,000. This compares with a historical mean harvest of 340,000 coho salmon (Figure 5). Most of the harvest during 1989 occurred in the set net fisheries on the westside of the Northern District and the eastside of the Central District of UCI. These two fisheries harvested nearly 64% of the total harvest of coho salmon in UCI during 1989 (Figure 6). Of these two fisheries, the set net fishery on the

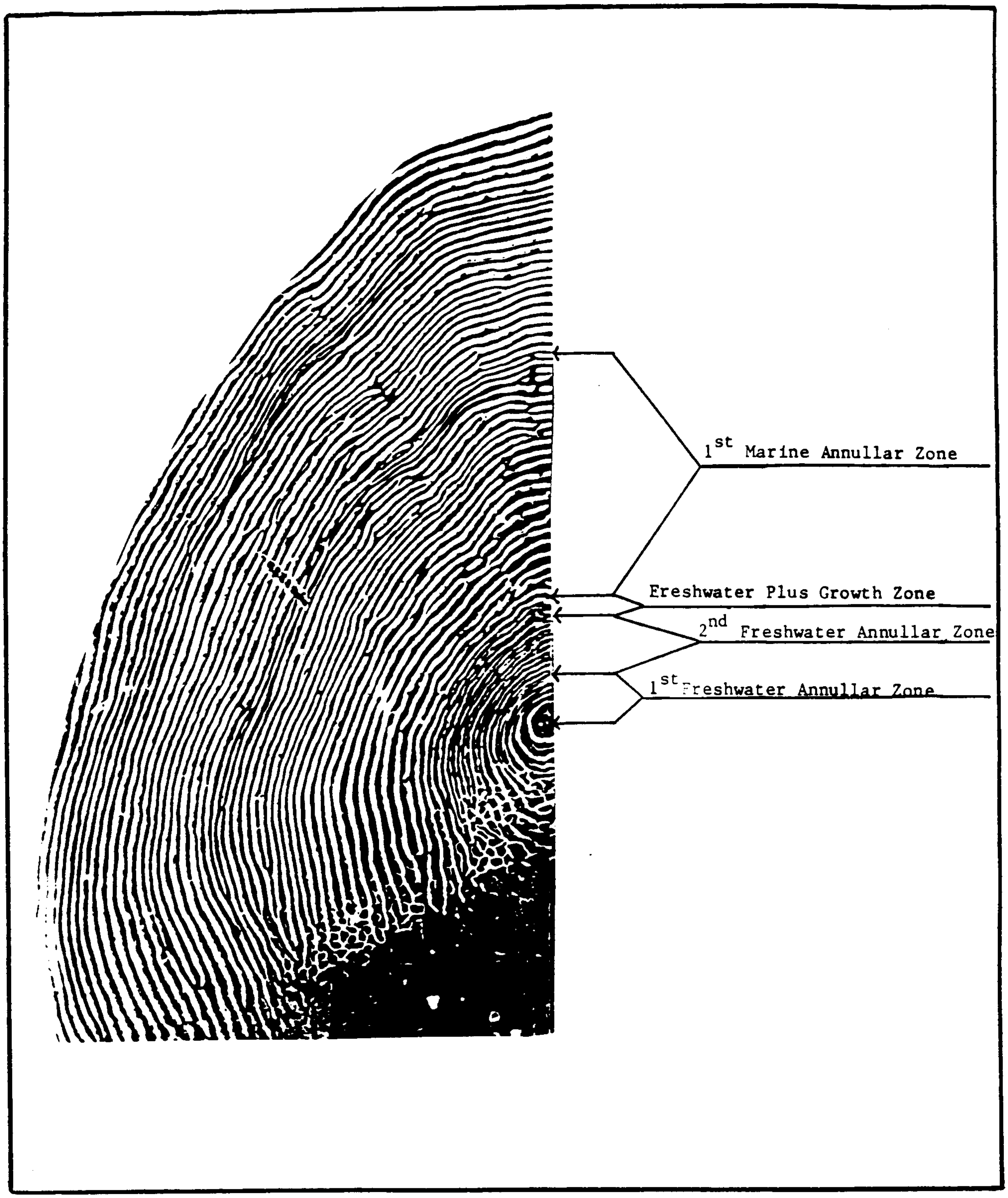

Figure 3. Depiction of a salmon scale showing the growth zones measured in the scale pattern analyses.

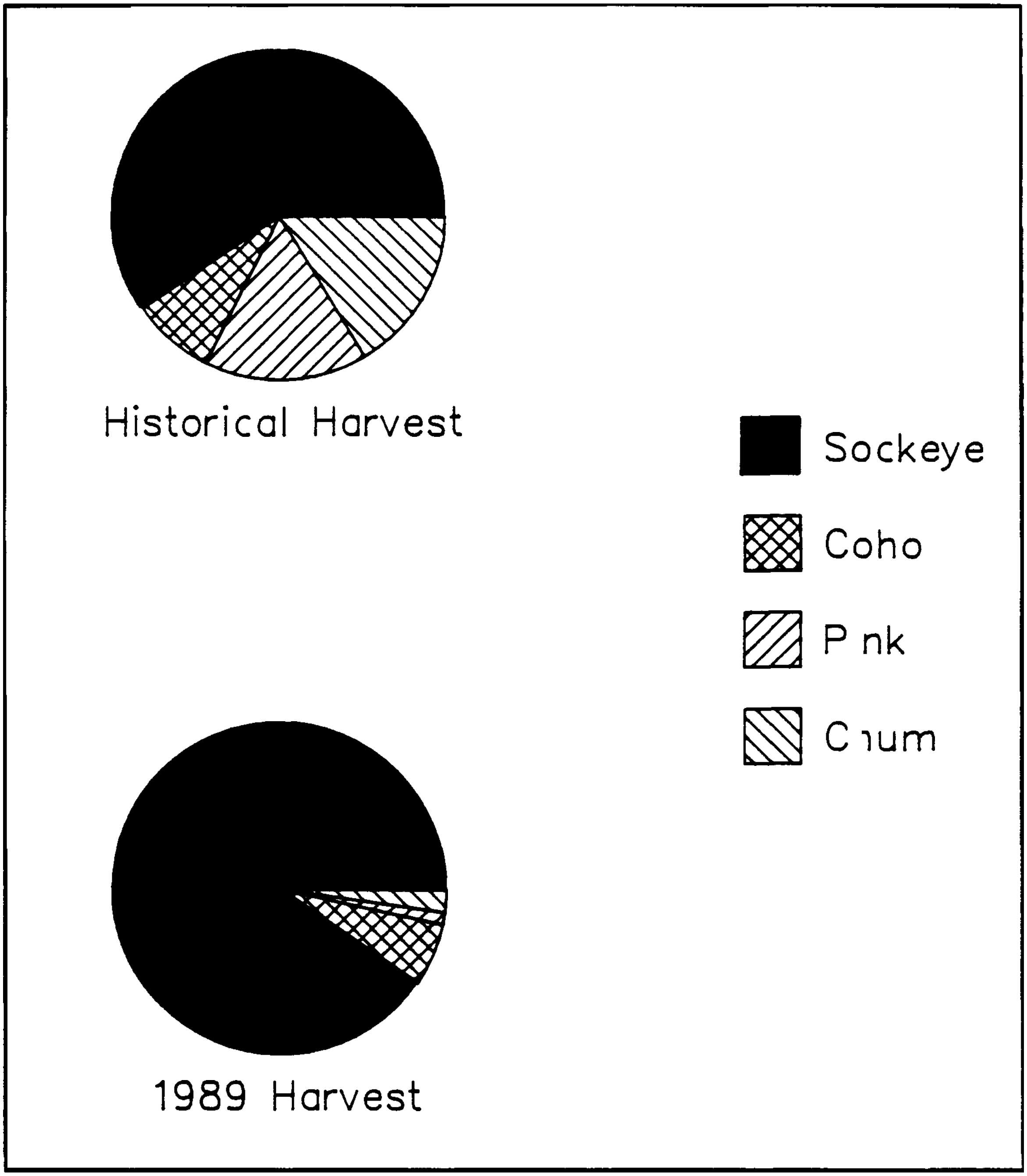

Figure 4. Species composition of the commercial harvest in upper Cook Inlet during 1989 in comparison to the historical composition.

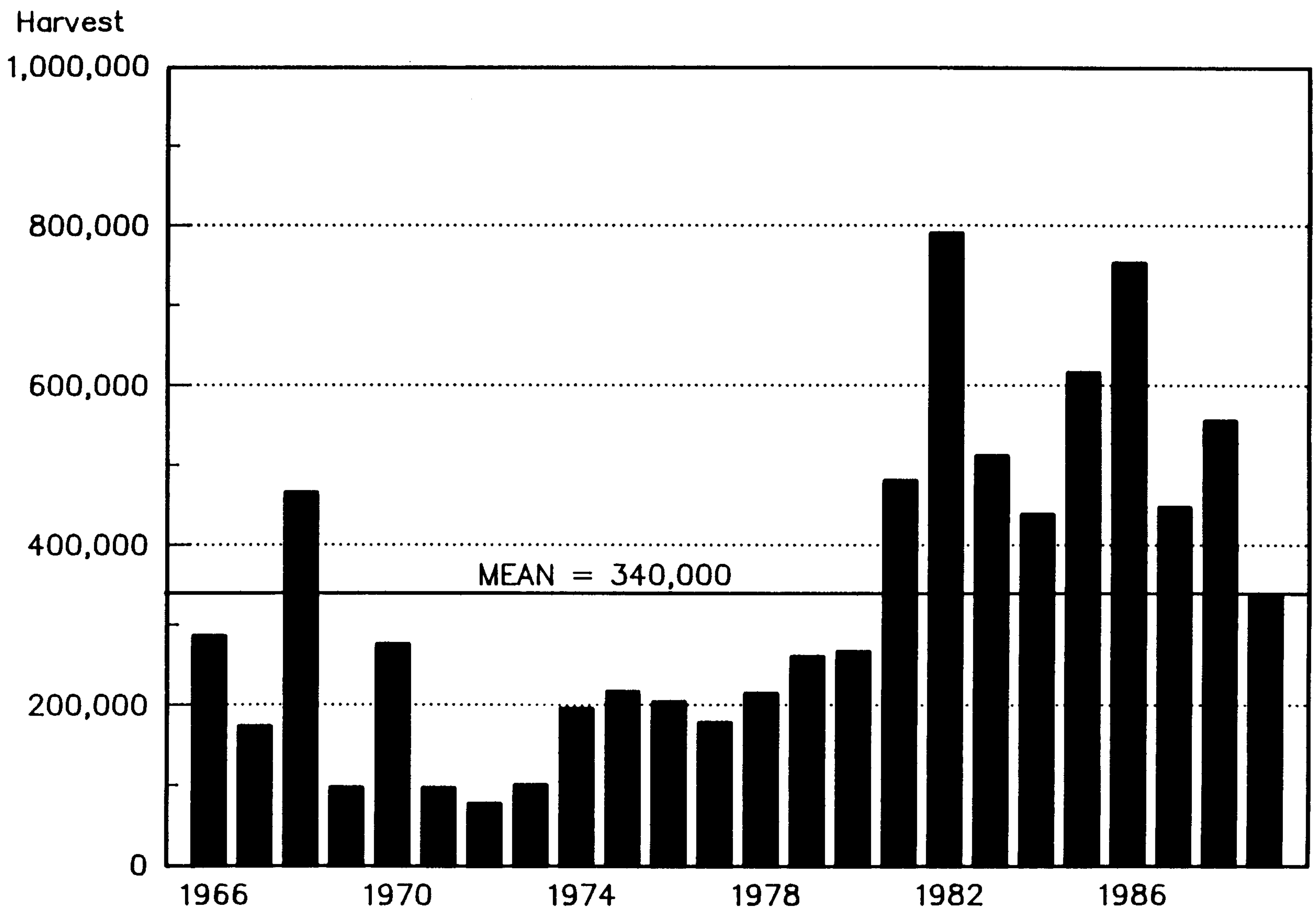

Figure 5. Historical harvests of coho salmon in the commercial fisheries of upper Cook Inlet, 1966 through 1989.

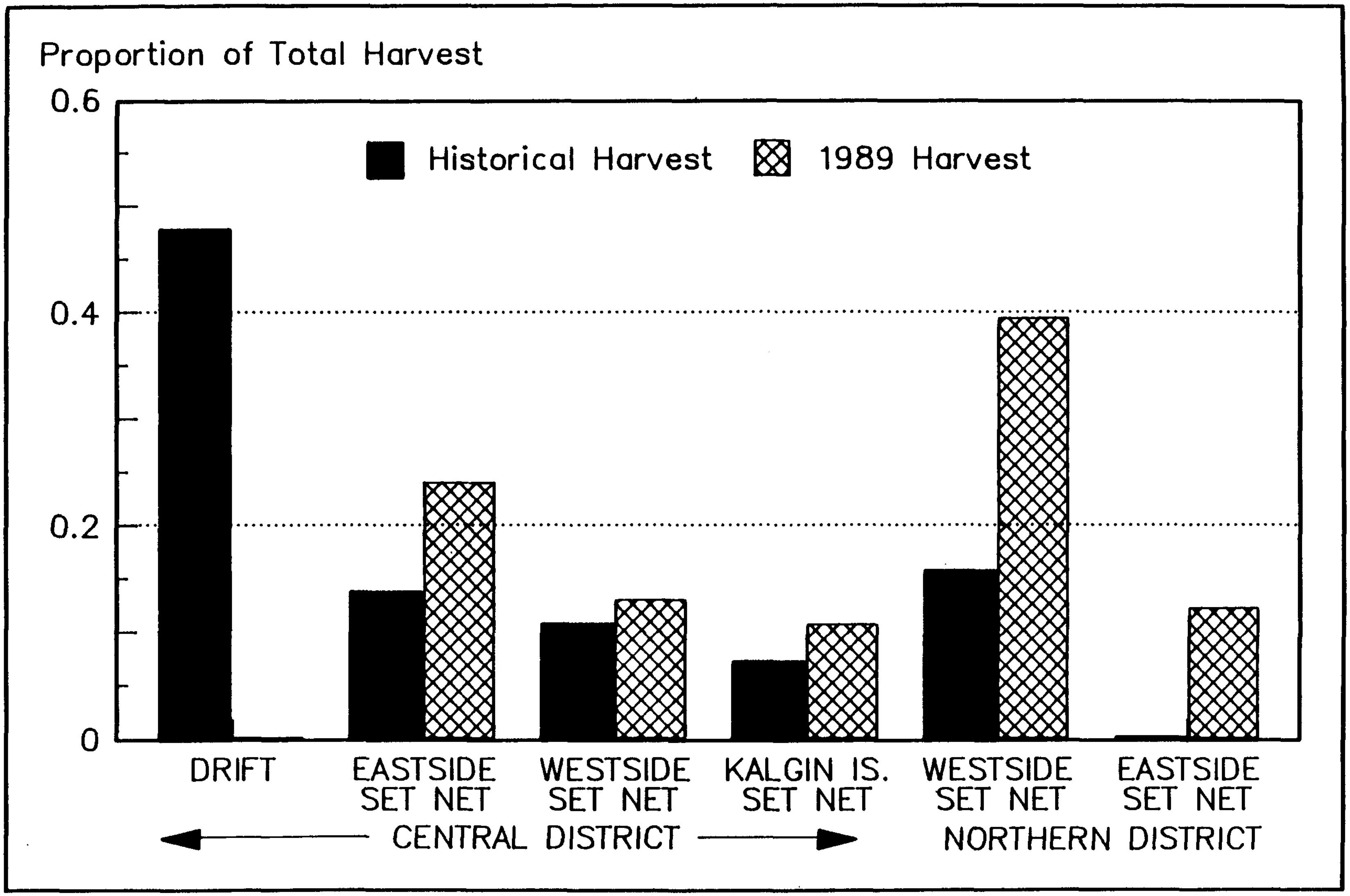

Figure 6. Proportional harvest, by fishery, of coho salmon in the various commercial fisheries of upper Cook Inlet during 1989 in comparison to the historical harvests.

westside of the Northern District was the largest, catching nearly 40% of the total harvest of coho salmon in UCI during 1989.

The distribution of the harvests of coho salmon in the commercial fisheries of UCI during 1989 varied from that observed historically (Figure 6). There was no harvest from the drift net fishery in the Central District during 1989. Historically, this fishery has harvested nearly 50% of the coho salmon harvested in UCI. The drift net fishery was closed during 1989 due to the oil spill from the EXXON Valdez. The largest fisheries for coho salmon during 1989 were the set net fisheries on the westside of the Northern District and the eastside of the Central District.

Harvests of coho salmon during 1989 peaked earliest in the set net fisheries on the eastside of the Central District and the westside of the Northern District and latest in the set net fishery on the westside of the Central District (Figure 7). Harvests in the set net fisheries on the east side of the Central District and the westside of the Northern District peaked during the week of 27 July whereas harvests in the set net fishery on the westside of the Central District peaked the weeks of 3 August and 24 August.

The species compositions of the harvest within the fisheries also changed over time. For example, in the set net fishery on the westside of the Northern District, salmon harvests before 28 July were predominantly comprised of sockeye salmon (Figure 8). After 28 July, coho salmon became an increasing component of the harvest.

In all sampled fisheries, age 2.1 coho salmon dominated the harvests during 1989 followed in order by age 1.1 coho salmon and age 3.1 coho salmon (Figure 9). Age compositions of coho salmon harvested from the commercial fisheries, however, were significantly ($P < 0.005$) different (Appendices A1 through A3). The differences are in the proportions of age 1.1 and age 3.1 coho salmon harvested in each of the fisheries. The set net fishery that occurred on the westside of the Central District had a higher proportion of age 1.1 coho salmon in its harvest than did the set net fisheries on the westside of the Northern District and the eastside of the Central District. The opposite was true for the age 3.1 coho salmon harvested in these fisheries. The set net fishery that occurred on the westside of the Central District had a lower proportion of age 3.1 coho salmon in its harvest than did the set net fisheries on the westside of the Northern District and the eastside of the Central District.

Although age 1.1 coho salmon were smaller than age 2.1 coho salmon and age 2.1 coho salmon were smaller than age 3.1 coho salmon in all the fisheries sampled, there were differences in the mean length-at-age of harvested coho salmon by each of the fisheries (Figure 10, Appendices A4 through A6). In general, the mean length-at-age of the coho salmon harvested in the set nets on the westside of the Northern and Central Districts was smaller than those harvested from the set nets on the eastside of the Central District.

The most popular gill net used by the commercial fisheries of UCI has 5-3/8" stretch mesh to target sockeye salmon (Hilsinger, personal communication). A selectivity curve for sockeye salmon (I could not find a selectivity curve

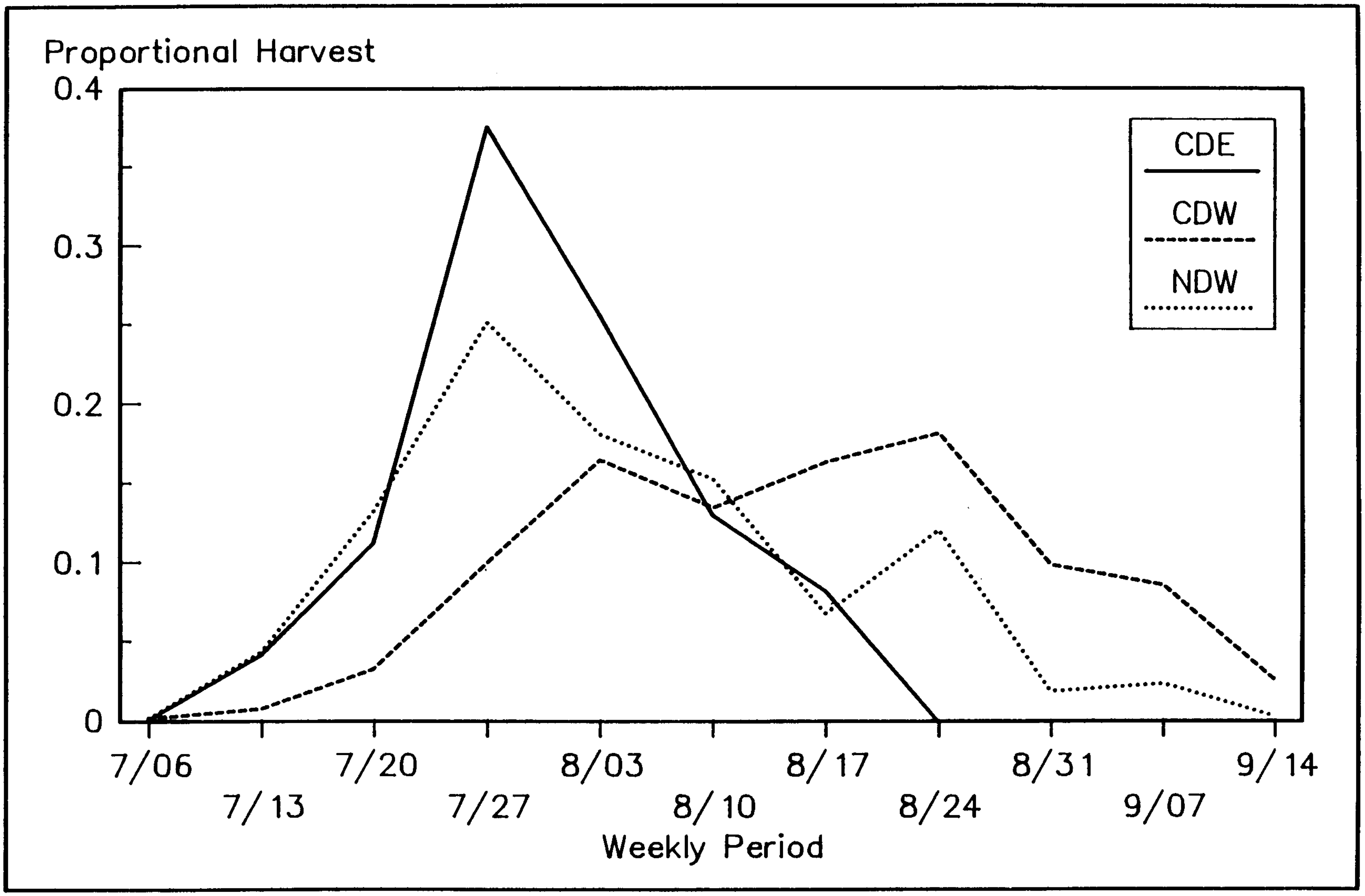

Figure 7. Proportional timing of harvests, by week, in the commercial set net fisheries on the eastside (CDE) and westside (CDW) of the Central District and the westside (NDW) of the Northern District of upper Cook Inlet during 1989.

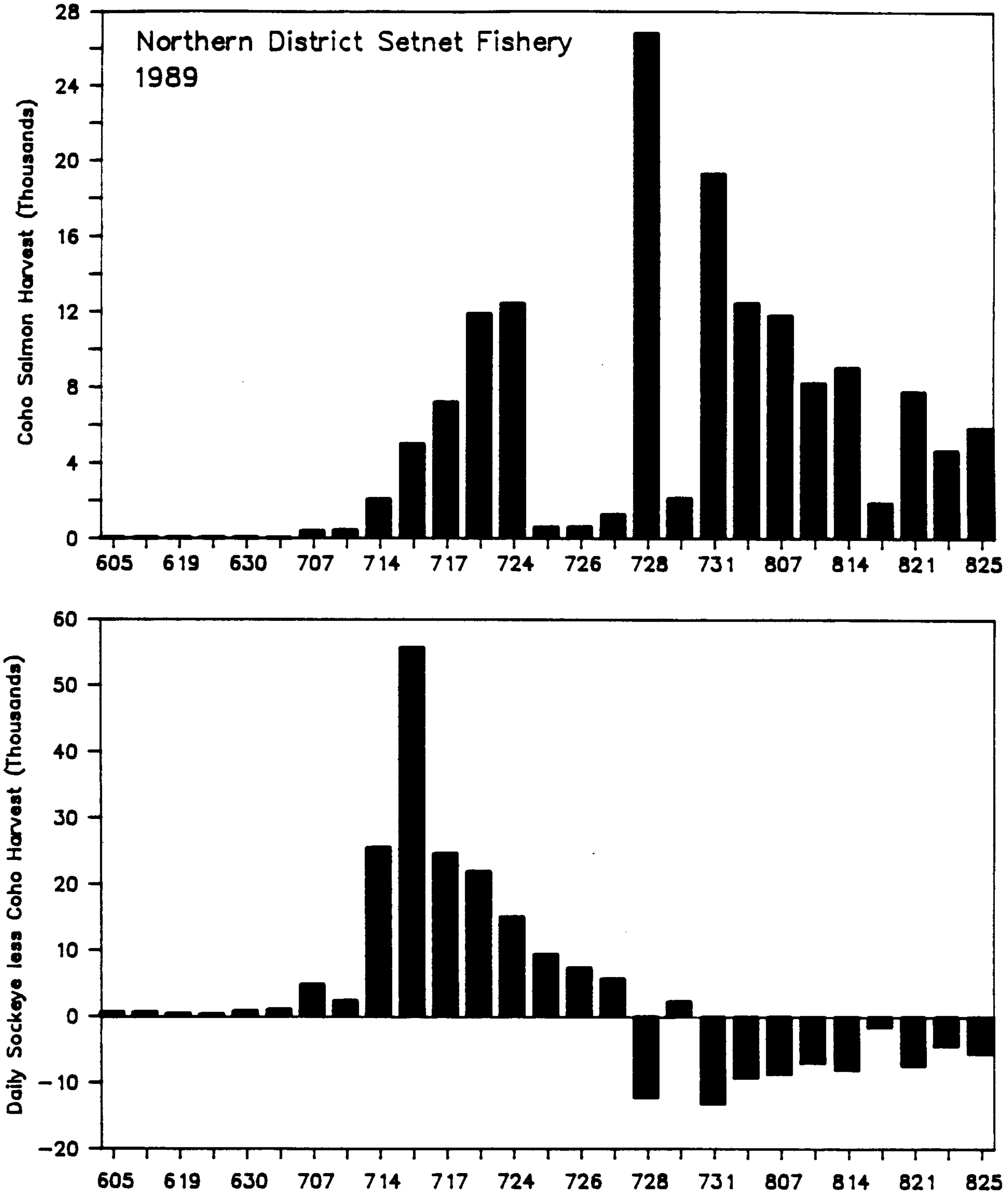

Figure 8. Species composition of harvests in the commercial set net fishery on the westside of the Northern District of upper Cook Inlet during 1989.

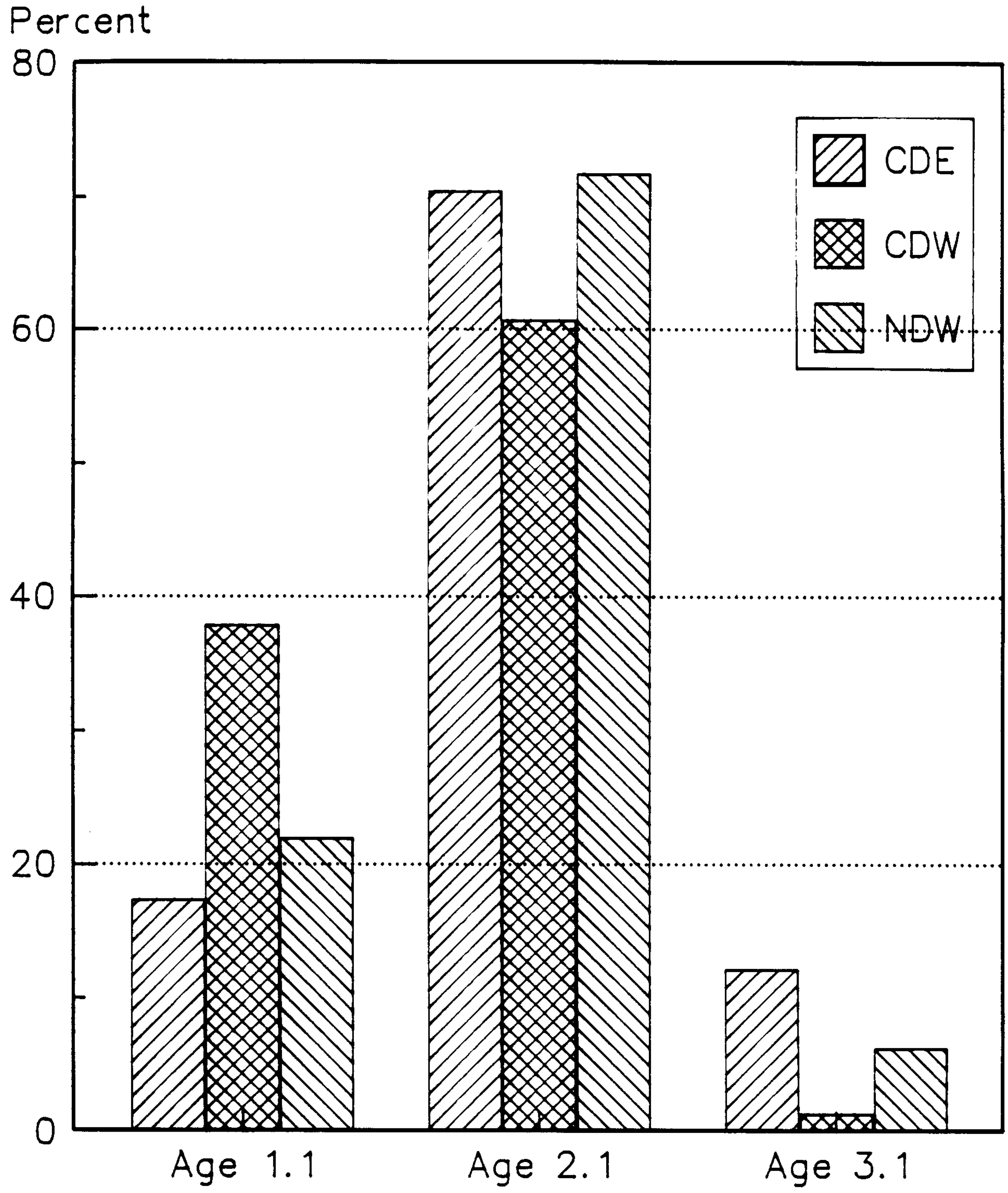

Figure 9. Estimated age composition of coho salmon harvested in selected commercial fisheries of upper Cook Inlet during 1989.

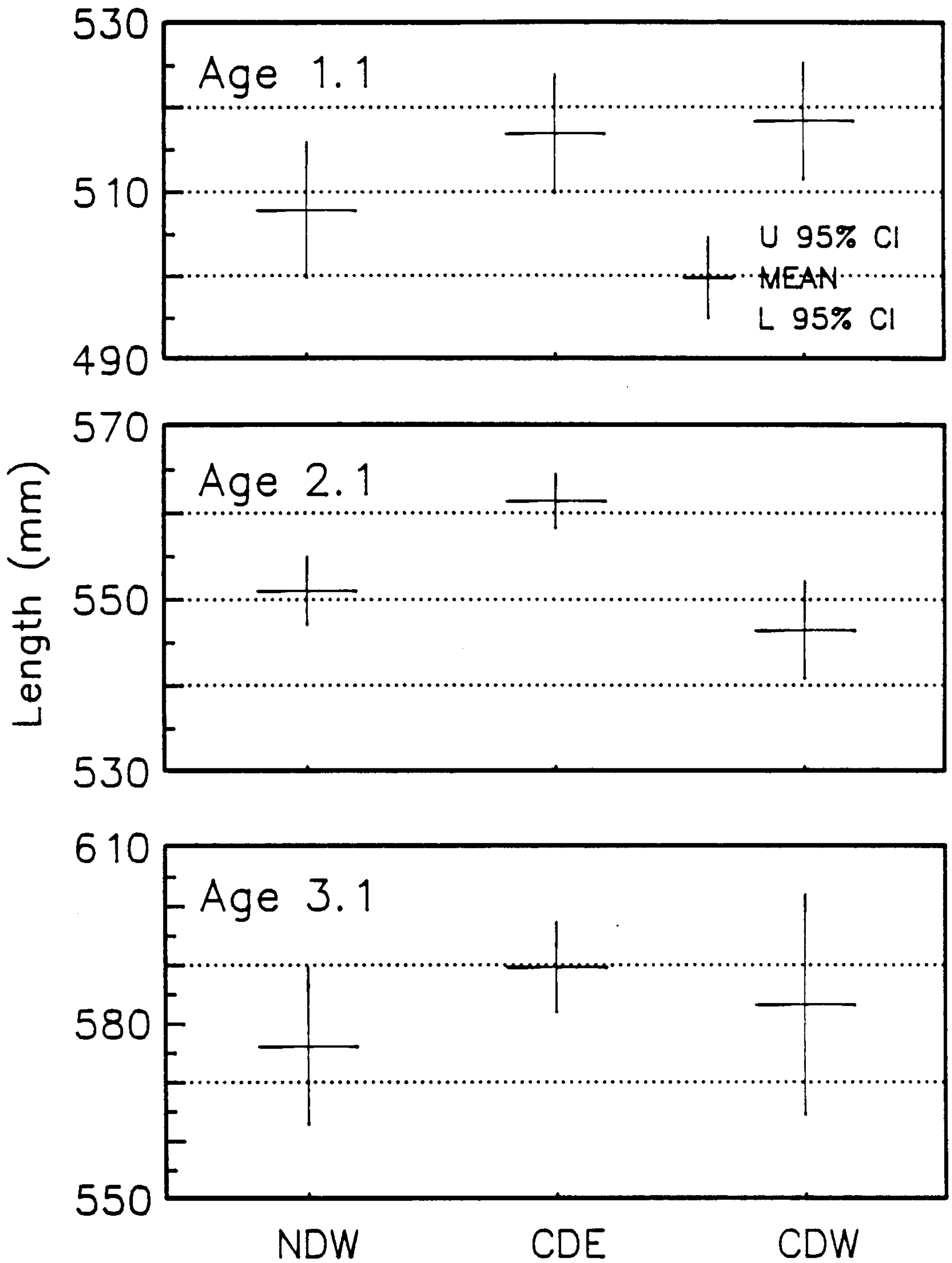

Figure 10. Estimated mean length-at-age for coho salmon harvested in selected commercial fisheries of upper Cook Inlet during 1989.

for coho salmon) for a 5-3/8" stretch mesh gill net (Brannian 1982) was plotted, as a selectivity curve for coho salmon was not available in the literature. As was the case in 1988, the peak of selectivity curve occurs on the ascending limbs of the relative length frequency curves for coho salmon harvested in the commercial fisheries during both 1988 and 1989 (Figure 11). This suggests that the gear used in the commercial fisheries is selective for smaller coho salmon.

<u>1989 Freshwater Escapements</u>

Coho salmon bound for the Susitna River enter fresh water earlier than do coho salmon bound for Little Susitna, Kenai, and Swanson Rivers (Figure 12). Entry timing of coho salmon into the Susitna River peaked during the week of 27 August, although a second, less pronounced, peak occurred during the week of 17 August. Entry timing of coho salmon into the Little Susitna and Swanson Rivers peaked during the weeks of 17 August and 24 August, respectively[3]. Entry timing of coho salmon into the Kenai River never peaked, but rather entered in relatively stable numbers throughout their immigration.

Age 2.1 coho salmon dominated in all the sampled escapements except the Little Susitna River where age 1.1 coho salmon dominated the escapement. This was due to a large return of stocked smolts and a poor return of wild stocks into the river. Age composition of coho salmon in the escapements, however, were significantly ($P < 0.005$) different (Appendices A7 through A10). A higher proportion of age 3.1 and a lower proportion of age 1.1 coho salmon returned to Kenai River than returned to the other drainages (Figure 13).

Differences also occurred in the mean length-at-age of harvested coho salmon by drainage (Appendices A11 through A14). The coho salmon that returned to Kenai and Little Susitna River drainages were generally larger over all age classes than coho salmon that returned to the Susitna and Swanson River drainages (Figure 14).

Age 1.1 coho salmon were smaller than age 2.1 coho salmon and age 2.1 coho salmon were smaller than age 3.1 coho salmon in all the escapements. There were differences, however, in the mean length-at-age of harvested coho salmon by each of the escapements (Figure 14, Appendices A11 through A14). In general, coho salmon escaping to the Susitna and Swanson Rivers were smaller at age than those escaping to the Kenai and Little Susitna River.

<u>LDF Classification Accuracy</u>

Age 2.1 scales were selected for analyses as this age class represented the major age class in all the sampled escapements and fisheries (Figures 9 and 13). The five scale pattern variables of age 2.1 coho salmon selected for

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[3] The entry timing of coho salmon into the Swanson River should be viewed with caution as the weir (used to estimate timing) washed out on 28 August.

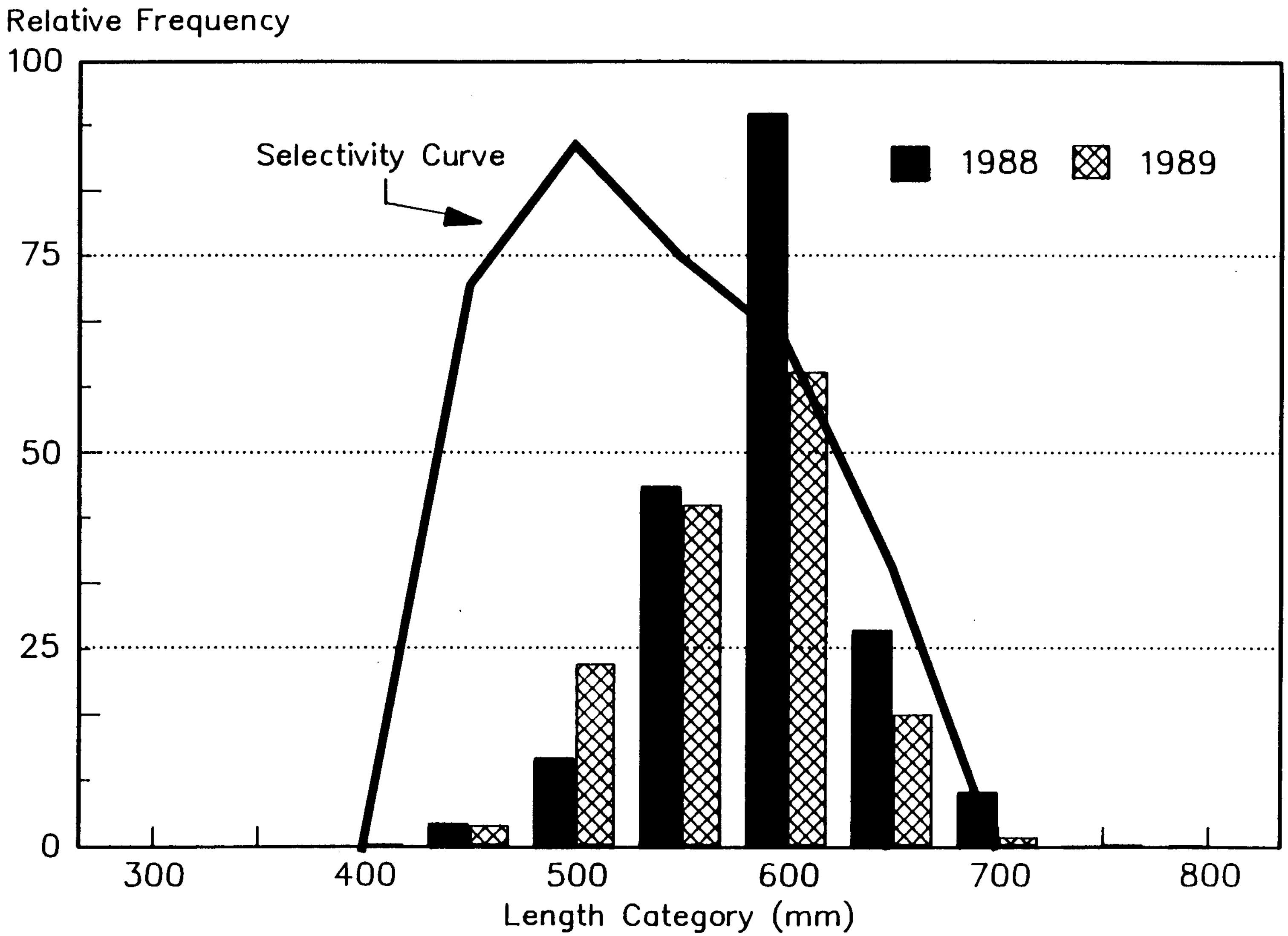

Figure 11. Length frequency of coho salmon harvested in selected commercial fisheries of upper Cook Inlet during 1988 and 1989 in comparison to a selectivity curve for 5-3/8" mesh gill net.

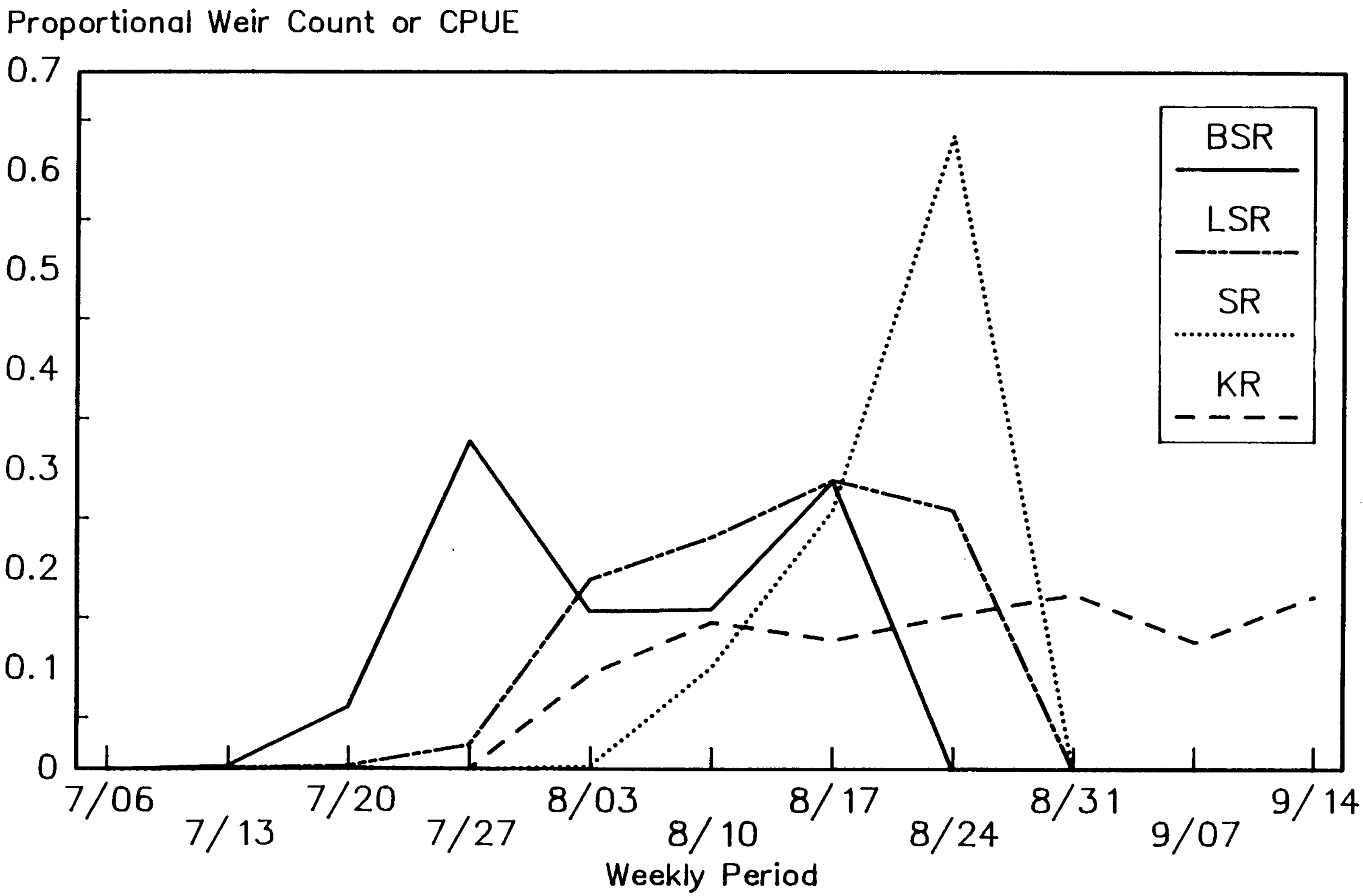

Figure 12. Migratory timing of coho salmon into the Susitna, Little Susitna, and Swanson Rivers and through the sport fishery on the Kenai River during 1989.

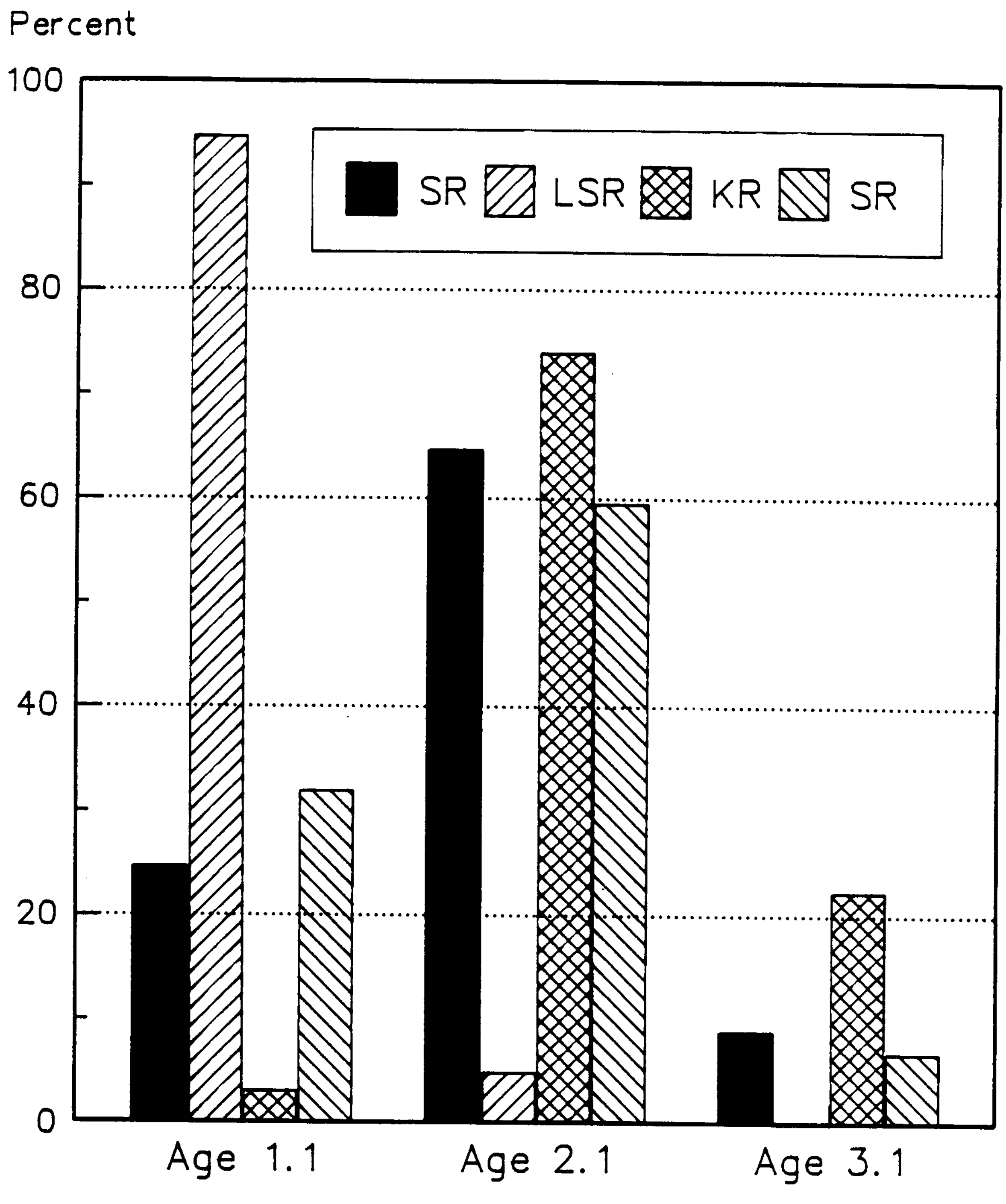

Figure 13. Estimated age composition for coho salmon in the escapements to the Susitna (SR), Little Susitna (LSR), Kenai (KR), and Swanson (SR) Rivers during 1989.

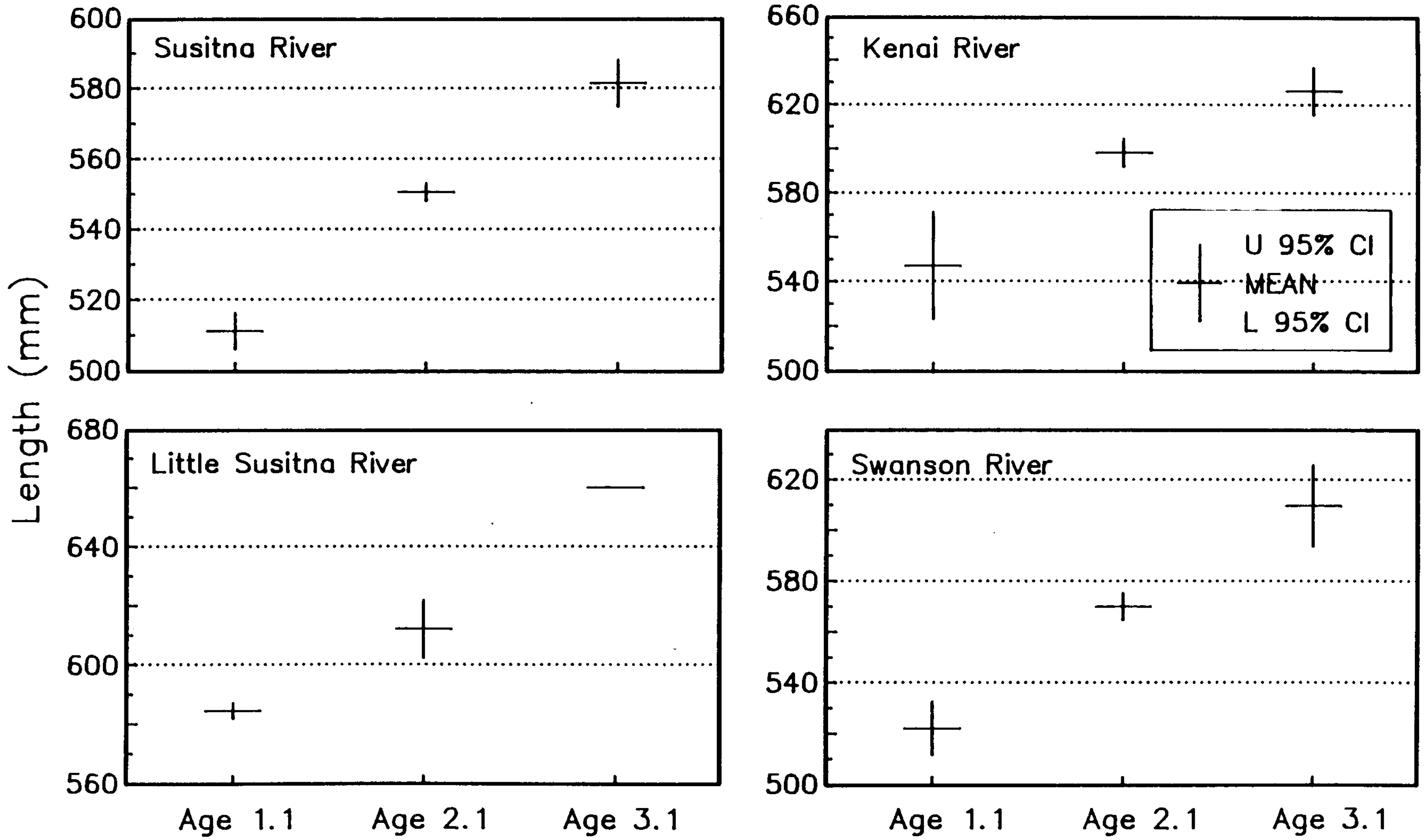

Figure 14. Estimated mean length-at-age for coho salmon in the escapements to the Susitna (SR), Little Susitna (LSR), Kenai (KR), and Swanson(SR) Rivers during 1989.

input into the LDF model were all freshwater growth characteristics (Table 7, Appendix B1). Three of the variables were associated with the first freshwater annular zone (Variable 1, 17, and 16), one with the second freshwater annular zone (Variable 57), and one with the overall freshwater annular zone (Variable 65). Four out of the five scale pattern variables selected for input into the model were not significantly ($P > 0.05$) correlated to length of the sampled fish (Table 8). Only the variable associated with the second freshwater annular zone (Variable 57), the last variable added to the model, was significantly ($P < 0.05$) correlated to length.

Differences were evident for each of the selected variables between scales from the evaluated stocks (Appendix B1, Table 7). The average number of first-freshwater circuli (Variable 1) was smaller for scales of coho salmon from the Kenai and Susitna Rivers than for scales of coho salmon from the Little Susitna and Swanson Rivers. The relative widths of selected first-freshwater variables (Variables 16 and 17) were larger for scales of coho salmon from the Kenai River than for scales of coho salmon from other stocks. The total number of freshwater circuli was greatest for scales of coho salmon from the Little Susitna and Kenai Rivers and least for scales of coho salmon from the Susitna and Swanson Rivers. The average interval between second-freshwater circuli was least for scales from the Kenai and Little Susitna Rivers and greatest for scales from the Susitna and Swanson Rivers.

Overall accuracy of the four-stock classification model was 56%; that is, the model was able to correctly classify the scales to their known river of origin 56% of the time (Figure 15). For specific stocks, the model was able to correctly identify Susitna River scales 61% of the time, Kenai River scales 59% of the time, Little Susitna River scales 44% of the time, and Swanson River scales 59% of the time. The model correctly classified scales of coho salmon from the Kenai, Susitna, and Swanson Rivers to their known river of origin more often than it did for scales of coho salmon from the Little Susitna River.

DISCUSSION

Only limited data are available to evaluate the proportional contribution of drainages to the total escapement of coho salmon to UCI. The information that is available indicates that the major drainages supporting coho salmon in the Northern District of the Inlet are the Susitna (Thompson et al. 1986) and Little Susitna Rivers (Bartlett and Conrad 1988) and in the Central District are the Kenai (Hammerstrom 1988) and Swanson (USFWS unpublished data) Rivers.

The observed differences in mean length-at-age and timing statistics reported by Vincent-Lang and McBride (1989) between specific freshwater escapements and commercial fisheries were again evident during 1989. As was the case in 1988, coho salmon that escaped to the Susitna and Swanson Rivers were smaller at age than those that escaped to the Kenai and Little Susitna Rivers. Also, as was the case in 1988, the coho salmon harvested by the set net fisheries on the westside of the Northern and Central Districts were smaller at age

Table 7. Statistics for scale pattern variables selected for input into the four-stock linear discriminant function.

Variable/Drainage[a]	Mean	Std. Error	F-Stat.	Correlation to 1st Variable
1 Number of Circuli in 1st Freshwater Annular Zone			43.175	---
BSR	10.139	0.319		
LSR	13.156	0.496		
KR	9.362	0.248		
SR	13.932	0.410		
17 Relative Width, (Distance Scale Focus to Circulus 4) / (Width of 1st Freshwater Annular Zone)			27.176	-0.900
BSR	0.590	0.015		
LSR	0.514	0.020		
KR	0.643	0.012		
SR	0.482	0.013		
16 Relative Width, (Distance Scale Focus to Circulus 2) / (Width of 1st Freshwater Annular Zone)			23.404	-0.900
BSR	0.387	0.012		
LSR	0.351	0.017		
KR	0.450	0.010		
SR	0.327	0.010		
65 Total Number of Freshwater Circuli			29.064	+0.450
BSR	25.917	0.373		
LSR	32.644	0.765		
KR	27.716	0.376		
SR	29.373	0.467		

-Continued-

Table 7. (page 2 of 2)

Variable/Drainage[a]	Mean	Std. Error	F-Stat.	Correlation to 1st Variable
57 Average Interval Between Circuli in 2nd Freshwater Annular Zone (Width of Zone/Number of Circuli)			29.064	
BSR	9.091	0.116		
LSR	8.835	0.158		
KR	8.276	0.090		
SR	9.429	0.172		

[a] BSR: Susitna River, LSR: Little Susitna River, KR: Kenai River, SR: Swanson River.

Table 8. Correlations of scale pattern variables selected for input into the four-stock linear discriminant function to fish length.

Variable		River[a]	R-squared[b]	P-Value
1	Number of Circuli in 1st Freshwater Annular Zone	BSR	4.0%	0.051
		LSR	0.7%	0.255
		KR	0.0%	0.956
17	Relative Width, (Distance Scale Focus to Circulus 4) / (Width of 1st Freshwater Annular Zone)	BSR	1.0%	0.115
		LSR	0.1%	0.312
		KR	0.0%	0.697
16	Relative Width, (Distance Scale Focus to Circulus 2) / (Width of 1st Freshwater Annular Zone)	BSR	0.0%	0.717
		LSR	0.1%	0.313
		KR	0.0%	0.885
65	Total Number of Freshwater Circuli	BSR	2.8%	0.086
		LSR	0.0%	0.730
		KR	0.0%	0.389
57	Average Interval Between Circuli in 2nd Freshwater Annular Zone (Width of Zone/Number of Circuli)	BSR	4.4%	0.042
		LSR	13.5%	0.008
		KR	3.7%	0.021

[a] BSR: Susitna River, LSR: Little Susitna River, and KR: Kenai River. Data not available for Swanson River.
[b] Correlation coefficient.

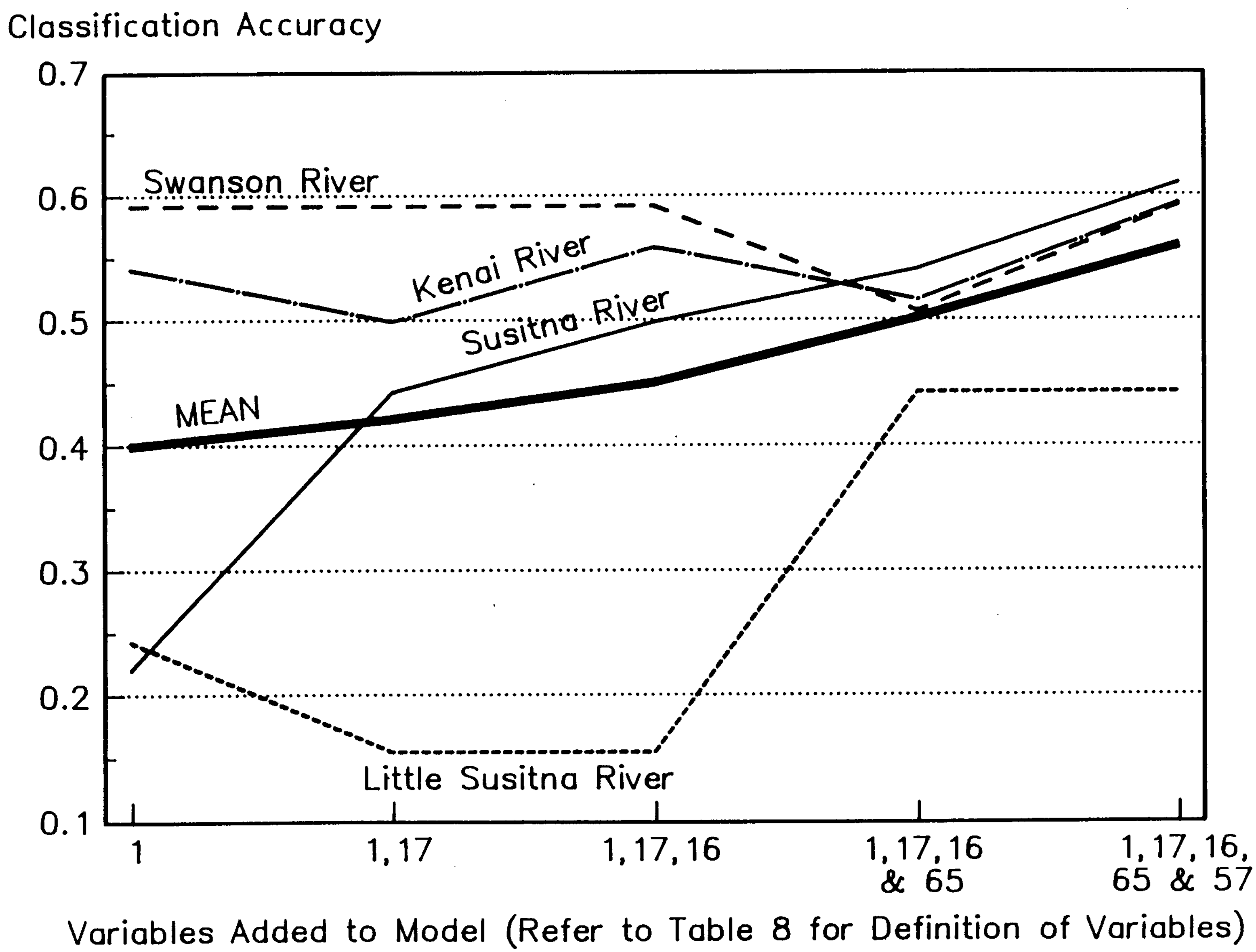

Figure 15. Accuracy of the linear discriminant function used to classify the four stocks of known origin in upper Cook Inlet during 1989.

on the westside of the Northern and Central Districts were smaller at age than those harvested in the set net fisheries on the eastside of the Central District. The timing of the harvests and escapements was also similar between the two years. Harvests peaked earliest during both years in the set net fisheries on the westside of the Northern District and latest in the set net fisheries on the eastside and westside of the Central District. Escapements of coho salmon peaked during both years earliest in the Susitna, Swanson, and Little Susitna Rivers and latest in the Kenai River.

Based on the observed differences in timing and length-at-age, Vincent-Lang and McBride (1989) hypothesized that most of the coho salmon harvested in the drift net fishery of the Central District and the set net fishery on the westside of the Northern District originated from Northern District streams, in particular the Susitna River, and that a majority of the coho salmon harvested in the set net fisheries on the west and east sides of the Central District originated from a mixture of Kenai Peninsula and Northern District streams. However, because of likely selectivity of the commercial gear towards smaller sized coho salmon which was also evident during 1989, they felt it was not possible to quantify these differences with length-correlated statistics.

The absence of a drift net fishery in UCI during 1989 allows for an examination of the effects of gear selectivity on the observed differences in mean length-at-age. If the observed differences in length-at-age are not solely a by-product of gear selectivity, then the absence of the drift net fishery should result in similar or larger observed differences in mean length-at-age between the set net fisheries and escapements in the two areas. This was not the case, however, in 1989 (Table 9). In all cases except one, the observed differences between the set net fisheries and escapements in the two areas were significantly less in 1989, suggesting that the observed differences are an artifact of observed gear selectivity.

Most of the coho salmon that would have been harvested in the drift net fishery in the Central District during 1989 were instead harvested in the set net fisheries in the Northern District. The set net fisheries of the Northern District had a record harvest of coho salmon during 1989, making it the largest fishery for coho salmon in UCI during 1989 (Figure 6). Historically, the set net fisheries of the Northern District harvest about 73,000 coho salmon or only about 16% of the total harvest of coho salmon in UCI. The proportion of coho salmon harvested in the set net fisheries along the eastside of the Central District also increased from historical proportions, but to a lesser extent than for the set net fisheries of the Northern District. During 1989, the set net fisheries on the eastside of the Central District harvested about 25% of the total coho salmon harvested in the commercial fisheries of UCI whereas these fisheries historically only harvest about 12%.

It may be possible that the larger harvests observed in the set net fisheries of the Northern District during 1989 were an artifact of larger escapements rather than the lack of a drift net fishery in the Central District. Escapement of coho salmon is not quantitatively monitored in any drainage of Cook Inlet except for the Little Susitna River. For this drainage,

Table 9. Differences in mean length-at-age observed between the escapements and set net fisheries in the Northern and Central Districts (east side only) during the years 1988 and 1989.

Comparison	Age 1.1	Age 2.1	Age 3.1
CDE-NDW[a]			
1988	94 (11)[b]	66 (4)	26 (5)
1989	36 (12)	48 (3)	45 (7)
Kenai-Susitna Rivers			
1988	41 (10)	27 (4)	44 (8)
1989	9 (6)	10 (3)	13 (8)

[a] CDE: Drift net fishery of the Central District
NDW: Set net fishery on the westside of the Northern District
[b] Standard errors in parentheses.

escapement of coho salmon was slightly less in 1989 (16,000, Bartlett In preparation)) than for 1988 (20,000, Bartlett and Vincent-Lang 1989). This suggests that the larger harvests observed in the set net fisheries of the Northern District during 1989 were not the result of significantly higher escapements.

Scale pattern analyses can be eliminated as a useful tool in accurately and precisely estimating the contribution of stocks in the commercial fisheries of UCI. Bethe (1977) and Robertson (1979) found that the first marine zone had the most discriminating power in their analyses of scales from the Kenai and Susitna River. However, Vincent-Lang and McBride (1989) showed that marine scale growth zone was significantly correlated to the length of fish. Because of probable gear selectivity in the commercial fisheries, variables in the marine growth zone are not usable for stock identification in UCI. Fortunately, the variables which proved to have the most discriminating power during the present investigation were all from the freshwater zone of scales and were not correlated to fish length. Unfortunately, this discriminating power was low. In a four-stock classification model, 25% classification accuracy is what would be expected from random chance. The best classification accuracy we reported above based on data from freshwater scale zones was 56%, or only about 30% better than chance only. A minimum classification accuracy of 70% would be needed to provide estimates of sufficient precision.

These results show that differences in mean length-at-age and scale patterns have been discarded as tools to estimate stock-specific contributions to the mixed-stock, marine fisheries for coho salmon in UCI; migratory timing and coded-wire tags remain to be tested. Estimation of migratory timing of stocks is not used in any of Alaska's mixed-stock fisheries to estimate stock-specific contributions when more than two stocks are present simultaneously. Migratory timings of stocks change annually to some extent and allocation of harvests which are based on differences in mean timing that may not occur in any one specific year may be in error. Coded-wire tags are implanted on juvenile fish and recovered from the fishery. Stock-specific contributions can be estimated through expansion of statistics of recovered tags, fraction of harvest inspected for tags, and fraction of return which is tagged. This technique is used in other fisheries for coho salmon in Alaska (Elliot et al. 1989) and is a well established procedure. For these reasons, a program using coded-wire tags would more likely produce accurate and precise estimates of the contribution of specific stocks of coho salmon to the mixed-stock, commercial fisheries of UCI than would analyses of migratory timing.

ACKNOWLEDGEMENTS

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APPENDIX A

Appendix A1. Estimated age composition of coho salmon harvested during 1989 in the set net fishery on the eastside of the Central District.

	Age Group				
Sex/Statistic	Unaged	1.1	2.1	3.1	TOTAL
<u>Unsexed</u>					
Sample Number		1	5		6
% of Sample		0.1	0.4		0.4
SE		0.07	0.16		0.17
<u>Females</u>					
Sample Number	42	110	419	57	628
% of Sample	3.0	7.7	29.4	4.0	44.1
SE	0.45	0.71	1.21	0.52	1.32
<u>Males</u>					
Sample Number	44	122	517	106	789
% of Sample	3.1	8.6	36.3	7.4	55.4
SE	0.46	0.74	1.28	0.70	1.32
<u>All</u>					
Sample Number	86	233	941	163	1423
% of Sample	6.0	16.4	66.1	11.5	100.0
SE	0.63	0.98	1.26	0.84	

Appendix A2. Estimated age composition of coho salmon harvested during 1989 in the set net fishery on the westside of the Central District.

	Age Group				
Sex/Statistic	Unaged	1.1	2.1	3.1	TOTAL
Unsexed					
Sample Number		1			1
% of Sample		0.2			0.2
SE		0.23			0.23
Females					
Sample Number	7	92	140	3	242
% of Sample	1.6	20.9	31.8	0.7	55.0
SE	0.60	1.94	2.22	0.39	2.37
Males					
Sample Number	13	66	115	3	197
% of Sample	3.0	15.0	26.1	0.7	44.8
SE	0.81	1.70	2.10	0.39	2.37
All					
Sample Number	20	159	255	6	440
% of Sample	4.5	36.1	58.0	1.4	100.0
SE	0.99	2.29	2.36	0.55	

Appendix A3. Estimated age composition of coho salmon harvested during 1989 in the set net fishery on the westside of the Northern District.

	Age Group				
Sex/Statistic	Unaged	1.1	2.1	3.1	TOTAL
Unsexed					
Sample Number			1		1
% of Sample			0.1		0.1
SE			0.10		0.10
Females					
Sample Number	21	95	360	34	510
% of Sample	2.0	9.1	34.6	3.3	49.0
SE	0.44	0.89	1.48	0.55	1.55
Males					
Sample Number	16	126	358	29	529
% of Sample	1.5	12.1	34.4	2.8	50.9
SE	0.38	1.01	1.47	0.51	1.55
All					
Sample Number	37	221	719	63	1040
% of Sample	3.6	21.3	69.1	6.1	100.0
SE	0.57	1.27	1.43	0.74	

Appendix A4. Estimated mean length-at-age of coho salmon harvested during 1989 in the set net fishery on the eastside of the Central District.

	Age Group				
Sex/Statistic	Unaged	1.1	2.1	3.1	TOTAL
<u>Unsexed</u>					
Average		482.00	592.75		570.60
SE			12.57		24.19
Sample Size		1	4		5
Minimum		482	567		482
Maximum		482	626		626
<u>Females</u>					
Average	560.56	514.78	557.06	580.45	552.67
SE	7.38	5.06	2.24	6.26	2.09
Sample Size	27	68	272	42	409
Minimum	464	444	426	464	426
Maximum	622	627	645	645	645
<u>Males</u>					
Average	581.46	519.14	564.18	594.50	562.98
SE	8.78	5.14	2.29	5.02	2.08
Sample Size	26	77	363	78	544
Minimum	445	420	444	501	420
Maximum	656	611	663	691	691
<u>All</u>					
Average	570.81	516.86	561.33	589.58	558.62
SE	5.84	3.59	1.62	3.96	1.49
Sample Size	53	146	639	120	958
Minimum	445	420	426	464	420
Maximum	656	627	663	691	691

Appendix A5. Estimated mean length-at-age of coho salmon harvested during 1989 in the set net fishery on the westside of the Central District.

Sex/Statistic	Unaged	1.1	2.1	3.1	TOTAL
	Age Group				
Unsexed					
Average		455.00			455.00
SE					
Sample Size		1			1
Minimum		455			455
Maximum		455			455
Females					
Average	533.33	515.69	539.36	589.00	531.20
SE	23.59	4.24	3.63	12.34	2.88
Sample Size	6	74	118	3	201
Minimum	434	454	434	565	434
Maximum	588	594	612	606	612
Males					
Average	580.50	523.30	555.21	574.50	546.41
SE	10.83	6.11	4.45	18.50	3.66
Sample Size	10	53	94	2	159
Minimum	522	418	440	556	418
Maximum	629	626	668	593	668
All					
Average	562.81	518.37	546.39	583.20	537.69
SE	12.18	3.56	2.87	9.62	2.31
Sample Size	16	128	212	5	361
Minimum	434	418	434	556	418
Maximum	629	626	668	606	668

Appendix A6. Estimated mean length-at-age of coho salmon harvested during 1989 in the set net fishery on the westside of the Northern District.

	Age Group				
Sex/Statistic	Unaged	1.1	2.1	3.1	TOTAL
Unsexed					
Average			517.00		517.00
SE					
Sample Size			1		1
Minimum			517		517
Maximum			517		517
Males					
Average	535.50	500.09	550.26	594.33	540.22
SE	23.35	5.98	3.26	11.02	3.17
Sample Size	4	57	165	12	238
Minimum	488	376	421	532	376
Maximum	587	597	645	649	649
Females					
Average	539.00	516.56	551.72	561.47	545.28
SE	8.98	5.38	2.50	6.72	2.28
Sample Size	11	50	196	15	272
Minimum	490	450	455	505	450
Maximum	572	599	660	601	660
All					
Average	538.07	507.79	550.96	576.07	542.87
SE	8.58	4.12	2.01	6.83	1.91
Sample Size	15	107	362	27	511
Minimum	488	376	421	505	376
Maximum	587	599	660	649	660

Appendix A7. Estimated age composition of coho salmon sampled from the Kenai River sport fishery during 1989.

	Age Group				
Sex/Statistic	1.1	2.1	3.1	4.1	TOTAL
<u>Females</u>					
Sample Number	4	102	31	1	138
% of Sample	1.4	36.8	11.2	0.4	49.8
SE	0.72	2.90	1.90	0.36	3.01
<u>Males</u>					
Sample Number	5	103	31		139
% of Sample	1.8	37.2	11.2		50.2
SE	0.80	2.91	1.90		3.01
<u>All</u>					
Sample Number	9	205	62	1	277
% of Sample	3.2	74.0	22.4	0.4	100.0
SE	1.07	2.64	2.51	0.36	

Appendix A8. Estimated age composition of coho salmon sampled at the Swanson River weir during 1989.

	Age Group					
Sex/Statistic	1.1	2.0	2.1	3.0	3.1	TOTAL
Unsexed						
Sample Number	3	1	4			8
% of Sample	1.5	0.5	2.0			3.9
SE	0.01	0.00	0.01			0.01
Females						
Sample Number	32	1	59	1	4	97
% of Sample	15.8	0.5	29.1	0.5	2.0	47.8
SE	0.03	0.00	0.03	0.00	0.01	0.04
Males						
Sample Number	30		58		10	98
% of Sample	14.8		28.6		4.9	48.3
SE	0.02		0.03		0.02	0.04
All						
Sample Number	65	2	121	1	14	203
% of Sample	32.0	1.0	59.6	0.5	6.9	100.0
SE	0.03	0.01	0.03	0.00	0.02	

Appendix A9. Estimated age composition of coho salmon sampled from the Little Susitna River (weir and sport harvest) during 1989.

	Age Group				
Sex/Statistic	1.0	1.1	2.1	3.1	TOTAL
Unsexed					
Sample Number		23			23
% of Sample		1.9			1.9
SE		0.00			0.00
Females					
Sample Number		488	23		511
% of Sample		41.1	1.9		43.1
SE		0.01	0.00		0.01
Males					
Sample Number	2	613	36	1	652
% of Sample	0.2	51.7	3.0	0.1	55.0
SE	0.00	0.01	0.00	0.00	0.01
All					
Sample Number	2	1124	59	1	1186
% of Sample	0.2	94.8	5.0	0.1	100.0
SE	0.00	0.01	0.01	0.00	

Appendix A10. Estimated age composition of coho salmon sampled from the Yentna River fishwheel site on the Susitna River during 1989.

	Age Group					
Sex/Statistic	1.0	1.1	2.1	3.1	4.0	TOTAL
<u>Unsexed</u>						
Sample Number			1			1
% of Sample			0.1			0.1
SE			0.00			0.00
<u>Females</u>						
Sample Number	1	209	492	57		759
% of Sample	0.1	13.3	31.4	3.6		48.4
SE	0.00	0.01	0.01	0.00		0.01
<u>Males</u>						
Sample Number		205	519	81	3	808
% of Sample		13.1	33.1	5.2	0.2	51.5
SE		0.01	0.01	0.01	0.00	0.01
<u>All</u>						
Sample Number	1	414	1012	138	3	1568
% of Sample	0.1	26.4	64.5	8.8	0.2	100.0
SE	0.00	0.01	0.01	0.01	0.00	

Appendix A11. Estimated mean length-at-age of coho salmon sampled from the Kenai River sport fishery during 1989.

	Age Group				
Sex/Statistic	1.1	2.1	3.1	4.1	TOTAL
Females					
Average	560.75	595.52	618.55	612.00	599.80
SE	15.43	4.56	7.36		3.90
Sample Size	4	102	31	1	138
Minimum	525	425	530	612	425
Maximum	600	680	700	612	700
Males					
Average	536.00	600.69	633.61		605.71
SE	18.33	4.83	8.30		4.37
Sample Size	5	103	31		139
Minimum	490	460	494		460
Maximum	590	710	710		710
All					
Average	547.00	598.12	626.08	612.00	602.77
SE	12.33	3.32	5.58		2.93
Sample Size	9	205	62	1	277
Minimum	490	425	494	612	425
Maximum	600	710	710	612	710

Appendix A12. Estimated mean length-at-age of coho salmon sampled at the Swanson River weir during 1989.

	Age Group					
Sex/Statistic	1.1	2.0	2.1	3.0	3.1	TOTAL
Unsexed						
Average	498.33	500.00	568.75			533.75
SE	30.87		25.03			20.28
Sample Size	3	1	4			8
Minimum	440	500	500			440
Maximum	545	500	620			620
Females						
Average	510.47	435.00	566.53	420.00	598.75	546.49
SE	7.29		3.38		11.25	4.61
Sample Size	32	1	59	1	4	97
Minimum	425	435	500	420	580	420
Maximum	580	435	610	420	630	630
Males						
Average	536.50		573.53		614.00	566.33
SE	7.65		4.39		10.80	4.32
Sample Size	30		58		10	98
Minimum	405		470		575	405
Maximum	630		650		675	675
All						
Average	521.92	467.50	569.96	420.00	609.64	555.57
SE	5.41	32.50	2.78		8.34	3.21
Sample Size	65	2	121	1	14	203
Minimum	405	435	470	420	575	405
Maximum	630	500	650	420	675	675

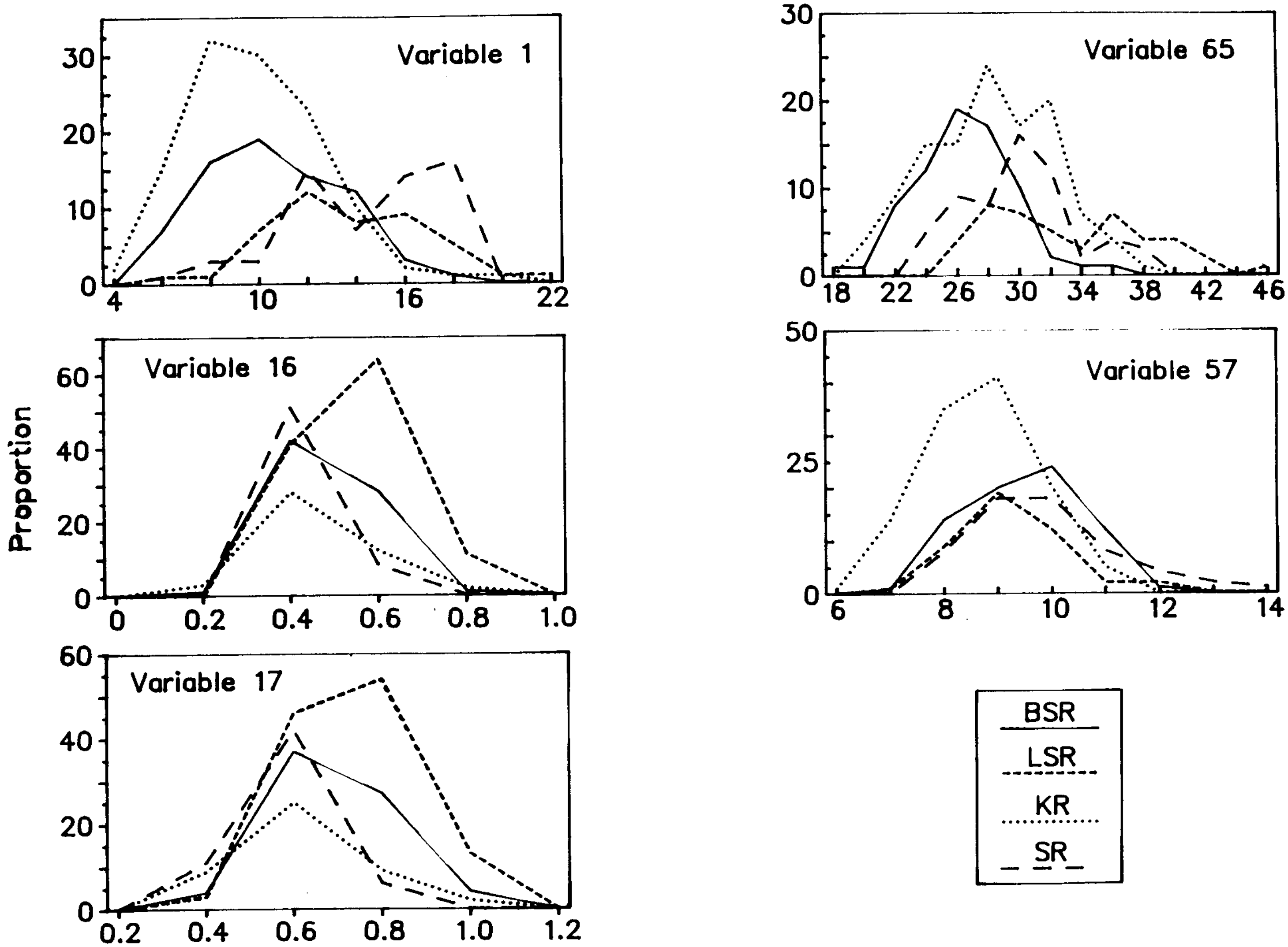
Appendix A13. Estimated mean length-at-age of coho salmon sampled from the Little Susitna River (weir and sport harvest) during 1989.

	Age Group				
Sex/Statistic	1.0	1.1	2.1	3.1	TOTAL
Unsexed					
Average		485.00			485.00
SE					
Sample Size		1			1
Minimum		485			485
Maximum		485			485
Females					
Average		574.72	595.22		575.65
SE		2.01	6.31		1.95
Sample Size		486	23		509
Minimum		53	520		53
Maximum		655	650		655
Males					
Average	620.00	592.16	622.92	660.00	594.05
SE	25.00	1.77	6.76		1.73
Sample Size	2	612	36	1	651
Minimum	595	370	495	660	370
Maximum	645	680	685	660	685
All					
Average	620.00	584.35	612.12	660.00	585.89
SE	25.00	1.35	5.08		1.32
Sample Size	2	1099	59	1	1161
Minimum	595	53	495	660	53
Maximum	645	680	685	660	685

Appendix A14. Estimated mean length-at-age of coho salmon sampled from the Yentna River fishwheel site on the Susitna River during 1989.

	Age Group					
Sex/Statistic	1.0	1.1	2.1	3.1	4.0	TOTAL
<u>Females</u>						
Average	495.00	517.76	549.51	580.96		543.06
SE		3.24	1.70	4.53		1.59
Sample Size	1	209	492	57		759
Minimum	495	400	400	500		400
Maximum	495	605	660	650		660
<u>Males</u>						
Average		504.36	551.44	581.67	325.00	541.68
SE		4.05	2.06	4.96	5.00	2.00
Sample Size		205	519	81	3	808
Minimum		375	390	460	320	320
Maximum		635	690	660	335	690
<u>All</u>						
Average	495.00	511.12	550.50	581.38	325.00	542.35
SE		2.61	1.34	3.45	5.00	1.29
Sample Size	1	414	1011	138	3	1567
Minimum	495	375	390	460	320	320
Maximum	495	635	690	660	335	690

APPENDIX B



Appendix B1. Distribution of the measurements for the selected scale pattern variables used for input into the four-stock linear discriminant function.